Impact of Shipper Collaboration on Carriers Selection in Reputation-Based Transportation Auctions

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Executive Summary

This paper proposes combinatorial transportation auction mechanisms to allocate transportation services to in Physical Internet (PI-π) context. We propose a centralized procurement auction in which a π-auctioneer runs a unique combinatorial auction of all shippers sending their freights through the π-network. The mechanism of reputation-based combinatorial auction for trucking services procurement is proposed to the Physical Internet paradigm in which goods travel in modular containers for the sake of interconnection in open networks. We address the problem of determining winning carriers (known as the Winner Determination Problem) based not only on bid prices but also on carriers service quality performances. The carrier reputation is translated to an unexpected hidden cost that represents the possible additional cost that the shippers may incur if some problems occur. The objective of this study is to decide on the winning bids knowing that: (1) a same contract may include shipping containers belonging to different shippers and (2) a carrier reputation may differ from one shipper to another. Different approaches are proposed to determine hidden costs. These approaches differ on the importance given to the shippers in evaluating the carriers and their bids. Such a centralized reputation-based transportation auction is beneficial on two levels. First, it exploits the synergy between the shipping contracts yielding possibly to lower bid prices. Second, it enables information sharing between shippers on the service quality performances of the participating carriers to help them have a more accurate judgment on carriers’ reputation.

Mechanism of π-auction

Physical Internet enables a centralized procurement auction in which (1) each shipper gives his orders (shipments) to his supply chain manager which dispatches, the lines of these orders over many π-containers and groups the lines of the orders having the same destination in common containers. When a container is ready for shipment, the supply chain manager transfers a notification to the routing agent, (2) the routing agent splits these shipments into segments and determines from these segments, potential segments (called in our context contracts) and transmits them to auction, (3) a π-auctioneer runs a centralized auction of all these contracts (4) transportation agents of each transportation company solves a Bid Construction Problem in order to determine the contracts to submit in the same package and the package bids prices; (5) π-
auctioneer solves the winner determination problem taking into account the reputation of carriers and obtain the winning bids and finally (6) the \(\pi\)-auctioneer solves the Cost Allocation Problem to decide the amount that each shipper will pay to each transportation company.

**Centralized Reputation-based WDP for Physical Internet**

(P1):

\[
\min \sum_{a \in A} \sum_{b \in B(a)} BP_b x_b + HC(b) x_b
\]

\[
\text{s.t. } \sum_{a \in A} \sum_{b \in B(a)} \delta_{bk} x_b \geq 1 \quad \forall k \in K,
\]

\[
x_b \in \{0, 1\} \quad \forall a \in A, b \in B(a).
\]

Where:

\[
HC(b) = \sum_{k \in K(b)} HC_{a(b),k}, \text{ and } a(b) \text{ is the carrier submitting bid } b.
\]

\[
HC_{a,k} = \sum_{\omega \in \Omega} C_{k,\omega} \times \Gamma_{a,\omega}
\]

\[
\Gamma_{a,\omega} = \sum_{e \in E(k)} w_{e,k} \Gamma_{a,\omega,e}
\]

To ensure fairness between different shippers we propose weighting the different valuations of shippers \(\Gamma_{a,\omega,e}\). \(w_{e,k}\) is the weight associated with the valuations of shippers \(\Gamma_{a,\omega,e}\). In the following, we propose three methods of determining weights \(w_{e,k}\) depending on the global, local and historical importance of the shipper.

**Global importance**: in this case we favour the shipper \(e \in E(k)\) that has the larger percentage of requested contracts (in the whole auction) when compared to other shippers having contracts in the auction.

\[
w_{e,k} = \frac{|K(e)|}{\sum_{e \in E(k)} |K(e)|}
\]

**Local importance**: Here, we favour the shipper that has the larger number of \(\pi\)-containers in the contract.

\[
w_{e,k} = \frac{|K(e)|}{\sum_{e \in E(k)} |K(e)|}
\]

**Historical importance**: in this case, we favour the shipper that has the higher level of knowledge of carrier \(a\) submitting bid \(b\) with regard to the other shippers having contracts in \(b\). This level of knowledge is through the number of shipments contracted in the past with the carrier. Formally, let \(|S(e,a)|\) denote the number of shipments of shipper \(e\) ensured in the past by carrier \(a\). Then, the weight \(w_{e,k}\) is computed as:

\[
w_{e,k} = \frac{|S(e,a)|}{\sum_{e \in E(k)} |S(e,a)|}
\]